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(71) Applicant 000002130
Sumitomo Denki Kogyo K.K.
Osaka-fu, Osaka-shi, Chuo-ku, Kitahama, 4-5-33
(21) Inventor Uozumi Takeshi
Osaka-shi, Konohana-ku, Shimaya 1-3
c/o Sumitomo Denki Kogyo K.K. - Osaka Plant
(21) Inventor Yasuda Norihiko
Osaka-shi, Konohana-ku, Shimaya, 1-3
c/o Sumitomo Denki Kogyo K.K. - Osaka Plant
(74) Agent Wada Akira

(54) [Name of the invention] Power cable for direct current

(57) [Abstract]
[Object] To provide a high voltage cable for direct current, whereby it is possible to prevent the accumulation of space charges caused by the applications of high voltages with direct current; a cable which also has good thermal resistance, comparable to that of insulating cables in XLPE.
[Structure]
This is a high voltage cable for direct current, wherein the insulant of the power cable for direct current is formed by a compound of cross-linked resin obtained by hot-cross-linking a compound of resins consisting of itaconic acid or crotonic acid, polyethylene and an organic peroxide. This cable allows the accumulation of space charges caused by the applications of high voltage with direct current to be prevented, has a better capacity for resistance to the disruptive forces of the direct current itself and good thermal resistance.
[Claims]
[Paragraph 1] Power cable for direct current, characterised in that it has, as an insulant, a compound of cross-linked resin, wherein itaconic acid or crotonic acid is used as polar monomer, and is obtained by hot-cross-linking a

compound of resins formed by the polar monomer, polyethylene (PE) and an organic peroxide.
[Paragraph 2] Power cable for direct current mentioned in paragraph 1, characterised in that it uses, as insulant, a resin product having insulating electrical properties, formed by 5 parts in weight of itaconic acid or crotonic acid as polar monomer, filled per 100 parts in weight of polyethylene.
[Paragraph 3] Power cable for direct current mentioned in Paragraph 1, characterised in that it uses, as organic peroxide, a peroxide for which the time of semi-disintegration at 130°C is more than 5 hours.
[Paragraph 4] Power cable for direct current mentioned in Paragraph 1, characterised in that it uses, as organic peroxide, 2.5-dimethyl-2.5-di(t-butyl peroxy)exine-3.
[Detailed description of the invention]
[0001]
[Field of industrial use] Our invention relates to a power cable for direct current.
[0002]
[State of the art] For transporting electrical energy over long distances and in high quantities, transport in the form of direct current does not cause any dielectric loss in the insulant, unlike the case of transport of electrical energy in the form of alternating current. Moreover systems for compensating the reactive component in relation to the charging current are not required.
[0003] Finally, [transport in the form of direct current] is considered advantageous in various respects, including the high dielectric resistance and the stability of the insulant.
[0004] Currently, for direct current cables with high voltage for the transport of this type of current, cables in OF are used, mostly made with low viscosity insulating oils and paper, which require feed systems for the oils and laborious maintenance work.
[0005] Vice versa, among insulating cables in plastic, for which no maintenance is required and which are used as power cables for alternating current, cables in cross-linked polyethylene (XLPE) are mainly used. Some types of cable for very high voltages with characteristics comparable to cables in OF are currently being developed.
[0006] However due to problems such as, for example, the characteristics of the space charges in relation to the direct current voltages, the use of these cables for direct currents with high voltage is limited.
[0007] The reason for their limited use is due to the considerable deterioration of the insulating characteristics, in the case wherein the space charges with negative polarity present in a cable in XLPE inside the insulant accumulate due to the application of a high direct current voltage.
[0008] For this reason, as an alternative to the cable in XLPE used to date, the development of a cable with solid insulant is advantageous.
[0009]
[Problems which the invention sets out to remedy] Generally it is considered that the degree of dielectric resistance of polyethylene increases with the increase in the degree of crystallisation. However it is thought that, when a continuous voltage is applied, the space charges which form when the electrical charges are injected through the electrode easily remain trapped at

the border between the zone of crystallised polyethylene and the zone of non-crystallised polyethylene.
[0010] Moreover, in order to resist, for example, deformation caused by possible current overloads, the solution adopted to date has been that of carrying out cross-linking, even if it is now known how the residues from cracking of the organic peroxide adopted as cross-linking agent increase the formation of space charges.
[0011] On these bases, since the characteristics of the space charges alter due to the polar groups, by filling the non-polarised polyethylene with a specific polar group and using specific organic peroxides, our inventors realised that it is possible to reduce the effect of the cracking residues and thus improve the characteristics of the direct current and, therefore, they have chosen this method.
[0012] Our invention was realised by taking account of the situation described hitherto, and its aim is that of producing a cable with high performances, specifying the polar group which is introduced into the polyethylene, limiting the weight of the filler, blocking the accumulation of space charges inside the insulant and using an organic peroxide which produces few cracking residues in order to obtain a cross-linked polyethylene which has high insulating properties and good thermal resistance in order to be used as an insulant.
[0013]
[Method for solving the problem] In order to solve the above problem, our invention uses, as polar monomer, itaconic acid or crotonic acid, and is based on a structure wherein a compound of cross-linked resin, obtained by cross-linking a hot resin compound, formed by the polar monomer, by polyethylene (PE) and by an organic peroxide, is adopted as insulant.
[0014] It is also possible to adopt, as an insulant, a compound of cross-linked resin, whose cross-linking is performed in a mixture of polyethylene, filled with a quantity smaller than 5 parts in weight of itaconic acid or crotonic acid, using 2.5-dimethyl-2.5-di(t-butyl peroxy)-exine-3 as cross-linking agent.
[0015]
[Implementation] The carbonyl of the itaconic acid or that of the crotonic acid acts as polar group and, distributing evenly inside the material, allows localised trapping of the space charges to be avoided.
[0016] Moreover, it is considered that, in the cracking residues of the organic peroxide which break up at high temperatures, the space charges accumulate to a lesser extent.
[0017] Thanks to the reduction in space charges, an improvement is obtained in the resistance to the disruptive forces of the direct current.
[0018]
[Embodiments] We shall now move on to the embodiments of our invention.
[0019] The power cable of our invention is based on a structure wherein the insulant is formed by a compound of cross-linked resin, in which itaconic acid or crotonic acid is used as polar monomer, and which is obtained by hot-cross-linking a compound of resins consisting of the polar monomer, polyethylene (PE) and an organic peroxide.
[0020] In forming the insulant which we have just described, using as insulant a compound of cross-linked resin whose cross-linking took place in a mixture of

polyethylene filled with a quantity less than 5 parts in weight of itaconic acid or crotonic acid and using, as cross-linking agent, an organic peroxide for which the time of semi-disintegration at 130°C is longer than 5 hours, for example 2.5-dimethyl-2.5-di(t-butyl peroxy)exine-3, we realised that it is possible to obtain a power cable for direct current with excellent characteristics as regards direct currents, including the accumulation of space charges.

[0021] In forming the insulant which we have just described, since there is the risk that a deterioration may occur in the properties in the solid state of the crystals in the case wherein the filling quantity of itaconic acid or crotonic acid is excessive in relation to that of the polyethylene and, as a result, the risk that there may be a decrease in the capacity of resistance to electrical voltage at high temperatures, it was considered that a quantity lower than 5 parts in weight can be adequate for the purpose. Moreover the addition of stabilisers normally adopted as additives in insulating materials does not cause any problem.

[0022] Table 1 shows the results of the first embodiment and of the comparison examples, whose details are given below.

[0023] The test samples were made using sheets produced with a mixture hot-pressed at a temperature of 180°C for 30 minutes, obtained by adding, as a cross-linking agent, 1 part in weight of dicumyl peroxide (DCP) and 2.5-dimethyl-2.5-di(t-butyl peroxy)-exine-3 (YPO) to the polyethylene filled with itaconic acid.

[0024] The evaluation relating to the accumulation of space charges was carried out by the pulsed electrostatic stress method, after having applied a voltage of 40 kV to the 2 mm sheet. The quantity of space charges accumulated is indicated by the number of + signs. The disruptive value of the direct current was measured at 90°C using a 0.2 mm sheet.

[0025]

[Table 1]

FIRST EMBODIMENT AND COMPARISON EXAMPLES

Samples	Quantity filled with itaconic acid (wt%)	Density (g/cm^3)	Organic peroxide		Disruptive value DC (kV/mm)	Quantity of space charges
			DCP	YPO		
Comparison example 1	-	0.92		1	120	R+++
Embodiment 1	0.5	0.92		1	139	M+
Comparison example 2	0.5	0.92	1		118	R++++
Embodiment 2	5.0	0.93		1	132	M+
Comparison example 4	10.0	0.93		1	115	M++

[0026] Table 2 moreover shows the results of the second embodiment and of the comparison examples. In the second embodiment, if we exclude the fact of having adopted, as polar monomer, crotonic acid, the test samples were produced in the same conditions as the first embodiment, and measuring also took place in identical conditions.
[0027]
[Table 2]

SECOND EMBODIMENT AND COMPARISON EXAMPLES

Samples	Quantity filled with crotonic acid (wt%)	Density (g/cm^3)	Organic peroxide		Disruptive value DC (kV/mm)	Quantity of space charges
			DCP	YPO		
Comparison example 1	-	0.92		1	120	R+++
Embodiment 1	0.5	0.92		1	137	M++
Comparison example 2	0.5	0.92	1		115	R++++
Embodiment 2	5.0	0.93		1	139	M+
Comparison example 4	10.0	0.93		1	117	M+++

[0028] Description of the symbols adopted in Table 1 and Table 2.
DCP: dicumyl peroxide (time of semi-disintegration at 130°C for 1.8 hours)
YPO: 2.5-dimethyl-2.5-di(t-butyl peroxy)-esin-3 (ditto, for 8.6 hours)
Space charges: M: accumulation of same charges, R: accumulation of differing charges.
[0029]
[Efficacy of the invention] From what we have disclosed hitherto, our invention enables the accumulation of space charges caused by the application of high voltages at direct current to be blocked, adopting as an insulant a compound of cross-linked resin whose cross-linking is carried out using 2.5-dimethyl-2.5-di(t-butyl peroxy)-exine-3 as cross-linking agent in a mixture of polyethylene filled with a quantity smaller than 5 parts in weight of itaconic acid or crotonic acid. Our invention also enables a cable to be produced for high voltage with direct current having good performances, comparable to those of insulating cables in XLPE.